Functionalized cotton fibres for sustainable antimicrobial textiles

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Sustainable antibacterial textiles offer a compelling alternative to synthetic polymers in hygiene and personal care applications. Cotton fibres are a biodegradable, cellulose-rich material with inherent softness, breathability, and renewability. However, achieving durable antimicrobial function without compromising fibre integrity or consumer comfort [1] remains an open challenge. A promising solution is to use metal-organic frameworks (MOFs) such as ZIF-8. However, the MOF crystal growth mechanisms at the cotton fibre surface, and the effects of the fibre's chemical and physical hierarchy on this process, remain unclear. X-ray diffraction (XRD) measurements of cotton composites conflate fibre paracrystallinity, random orientation distributions, and coating heterogeneity into averaged signals that cannot resolve the underlying interfacial chemistry. To overcome this, we have adopted a multi-scale scattering approach to investigate the MOF crystal growth mechanism on model surfaces and on single cotton fibres. In particular, nano-focused XRD [1] provided unprecedented spatial resolution on the fibre crystal planes.

For our cotton fibre functionalization, ZIF-8 was grown *in situ* on non-woven cotton under mild, room-temperature aqueous conditions and subsequently functionalised with *curcumin* , a natural antimicrobial, and biopolymer layers of chitosan and hyaluronic acid. [2] Wide-angle X-ray scattering (WAXS) showed homogenous ZIF-8 deposition via the sodalite-phase Bragg peaks (Fig.1b) [3] . At the single-fibre level, nano-focused XRD with simultaneous X-ray fluorescence mapping revealed that ZIF-8 attachment, on the contrary, at this level was spatially heterogeneous, with the cellulose I (200) and (110) planes exhibiting a strong orientation dependence. The results on the single-fibre level with unprecedented spatial resolution thus unravelled the crystal structural details previously unreported on a macroscopic fabric level.

Complementary antimicrobial screening has revealed broad-spectrum activities of the functionalised fabrics against *E. coli* and *S. aureus,* attributed to the synergistic combination of ZIF-8 and *curcumin* . ZIF-8 mediates zinc ion-mediated toxicity against Gram-negative bacteria, whilst curcumin disrupts membranes of Gram-positive species [2,4] . These findings demonstrate the antimicrobial efficacy of MOF-functionalised cotton and provide nanostructural characterisation at the single-fibre level; a resolution demanded by the material's hierarchical interfacial complexity. Together, they establish both a mechanistic framework for functional textile design and a scalable route to next-generation antimicrobial textiles for wound care, period products, and beyond.

Keywords:

ZIF-8, cotton functionalisation, nano-focused X-ray diffraction, single-fibre characterisation, antimicrobial textiles.

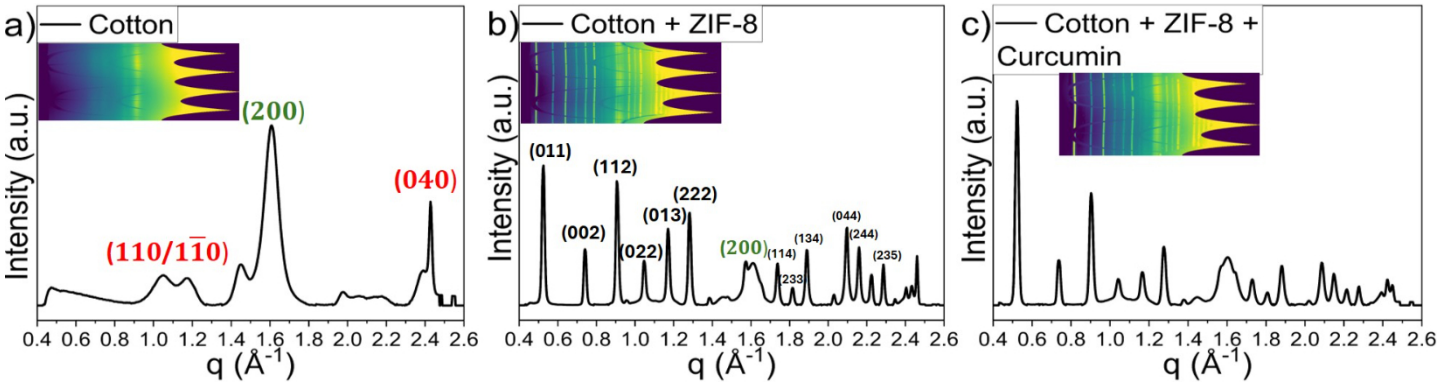

Figure 1 WAXS diffractograms of non-woven cotton: (a) unmodified cotton, (b) cotton with ZIF-8: Sodalite Miller indices indicated, and (c) cotton with both ZIF-8 and curcumin. Insets show azimuthally integrated 2D diffractograms.

References:

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